

An Efficient Air-Fuel Ratio Controller for Diesel Engine to Reduce the Environmental Hazards through Fuzzy Logic Controller

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ABSTRACT:-The aim of this proposal is to reduce the input for the diesel engine and use the input of fuel to the engine in economically without any extra energy. Due to the unburnt fuel the exhaust gas will be more and it will reduce the engine efficiency and also make the environmental pollutions. Due to high compression ratio and lack of ignition time of fuel is the reason for production of exhaust gas from the engine. The monitoring of air fuel ratio and speed of the engine is the input to the controller for controlling the fuel input. The speed will be monitored by the speed sensor like speedometer and exhaust gas will be filtered by carbon remover. The filtered gas will be heated by heater for increasing the energy of the filtered gas. It is the additional energy to the engine for reducing the fuel input to the engine. The fuzzy controller takes the input as speed and additional energy of the engine. The observations of engine speed and additional energy by the sensors will give the input to the fuzzy controller and it will control the fuel input as per the additional energy level. Through the using of waste energy it will help to increase the performance and efficiency of the engine and also reduce the environmental pollutions too.

KEYWORDS: fuel consumption rate, Fuzzy Logic Controller, Fuzzy Inference System, Unburnt Gas.

I. INTRODUCTION

To reducing the unburnt gas and engine operated in safe mode, they are monitoring the engine vibrations and noise. If the vibrations and noise level is more than safety level the controller will reduce the fuel injection level to the engine and to operate the engine in safety mode, it is the way they are used now. This project introducing an idea, which is monitoring the speed and exhaust level and if the level of exhaust is more and it is feedback to the engine as additional energy. During the operation of diesel engine the variations of speed is depending upon the load was connected with the engine. So the speed of the engine is the main factor for producing of exhaust gas. Because the speed was more means the burning of fuel was also more. So that time of period the unburnt fuel was more due to fast operation of the crank shaft, piston and valves and lack of fuel injection time.

By removing the carbon particles in the exhaust gas with help of carbon filters it will be used as additional energy. When the exhaust gas is more than the safety level then the carbon filter will filter the carbons. Thereafter the filtered gas energy level should be reduced due to process of filters. So adding of heat energy to the filtered gas by the heater is way to improving the energy level of the filtered gas and it is the additional energy to the engine.

A. Methodology

The following methodology was adopted to develop the system.

i. Monitoring of Engine operation

The observations of engine speed and exhaust gas is the input to the controller. So the speed will be monitored by speed sensor and the level of additional energy from exhaust gas will be monitored by the calculation of controller.

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ii. Creation of Additional Energy

In the exhaust gas the carbon particles are highly presented. So the removing of carbon particles with help of UFH portable carbon dioxide filter and it was heated externally by the heater. So the heated gas will helps to reduce the compression ratio of the diesel engine when it is used as the additional energy to the engine.

iii. Controller action

If the level of additional energy to the engine is more means the fuel input to the engine will reduce. And also the input of additional energy level was less means the fuel input to the engine will increase as per the load connected to the engine and needed.

II. PROPOSED MODEL

The first requirement for monitoring of engine operation is to measure the speed of the engine before it will transmit to the load. Because the load speed will be differ from the engine speed due to the gear system. So the monitoring of speed is the first input to the controller. The controlling action gets the input as listed below:

- i. Sensors to detect the speed of the engine continuously for finding the variations of speed.
- ii. Additional energy from the heater was monitored by the gas sensors.
- iii. A fuzzy controller takes the control action against fuel input to the engine as per the range of speed and additional energy.

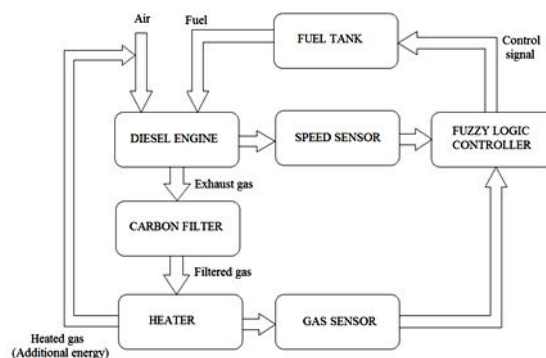


Fig.1 Block Diagram of Proposed model

The most commonly used for detecting the speed of the engine is speedometer and range of the additional energy gas sensor. The level of the exhaust value is very small after the filtration process. So it should be need some additional energy for reuse. Therefore the heater heats the filtered gas for adding some energy to the gas.

A. Restrictions on Engine Speed and Power

For the engine power polynomial, there are restrictions on the polynomial coefficients p_i , to achieve a valid power-speed curve. These restrictions are detailed below.

- i. If you use tabulated power or torque data, corresponding restrictions on $P(\Omega)$ remain. Set $w = \Omega/\Omega_0$ and $p = P(\Omega)/P_0$, and $w_{\min} = \Omega_{\min}/\Omega_0$ and $w_{\max} = \Omega_{\max}/\Omega_0$. Then,
 - ii. The engine speed is restricted to a positive range above the minimum speed and below the maximum speed: $0 \leq w_{\min} \leq w \leq w_{\max}$.
 - iii. The engine power at minimum speed must be nonnegative: $p(w_{\min}) \geq 0$. If you use the polynomial form, this condition is a restriction on the p_i :

$$p(w_{\min}) = p_1 \cdot w_{\min} + p_2 \cdot w_{\min}^2 - p_3 \cdot w_{\min}^3 \geq 0$$
 - iv. The engine power at maximum speed must be nonnegative: $p(w_{\max}) \geq 0$. If you use the polynomial form, this condition is a restriction on w_{\max} : $w_{\max} \leq w_+$.

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B. MATLAB

MATLAB is a programming environment ideally suited for scientific computations that require a large use of arrays or graphical analysis of data. The syntax of the programming code is very similar to C, and is also very forgiving for errors made by the programmer. It is an interpreted language, meaning that no compiler is needed, and scripts are saved as “.m” files. Another important note is that array indices begin with a 1, compared to a 0 in Java or C.

One of the most powerful aspects of MATLAB is that many commonly used functions are already built-in to the program. For example, array-sorting algorithms, Hough transforms and so on, are quickly and easily implemented because of this. This allows MATLAB to be a very useful environment for testing out approaches to solving problems before committing them to C or Java, or other programming languages.

a. Fuzzy Logic Controller

The point of fuzzy logic is to map an input space to an output space, and the primary mechanism for doing this is a list of if-then statements called rules. All rules are evaluated in parallel, and the order of the rules is unimportant. The rules themselves are useful because they refer to variables and the adjectives that describe those variables. Before you can build a system that interprets rules, you must define all the terms you plan on using and the adjectives that describe them. To say that the water is hot, you need to define the range that the water's temperature can be expected to vary as well as what we mean by the word hot. The following diagram provides a roadmap for the fuzzy inference process. It shows the general description of a fuzzy system on the left and a specific fuzzy system on the right.

b. Design of FLC

To design a Fuzzy Logic Controller the following steps to involve:

- i. Add Input variables.
- ii. Add Output variables.
- iii. Assign the membership function values to input variables.
- iv. Assign the membership function values to output variables.
- v. Set the Fuzzy Rules.
- vi. Export the FIS values to FLC.

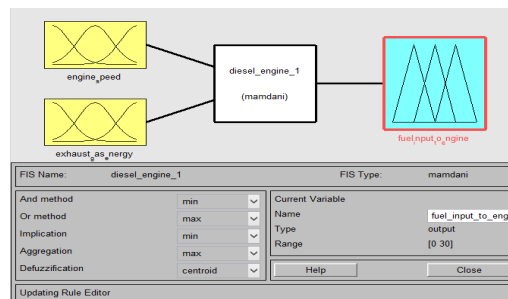


Fig.2 Design of Fuzzy Logic Controller.

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The following membership functions are used in this proposal:

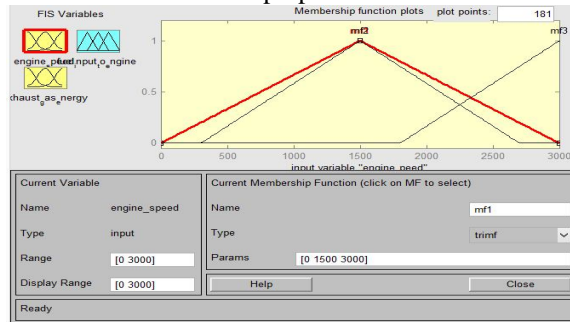


Fig.3 Membership functions of Engine speed.

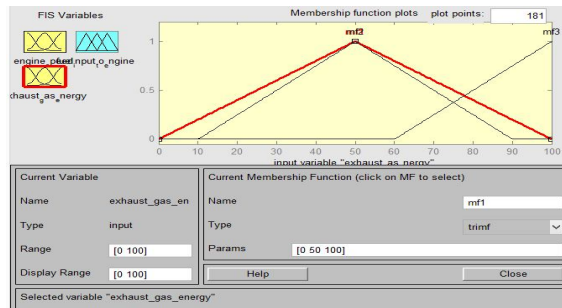


Fig.4 Membership functions of Exhaust gas energy.

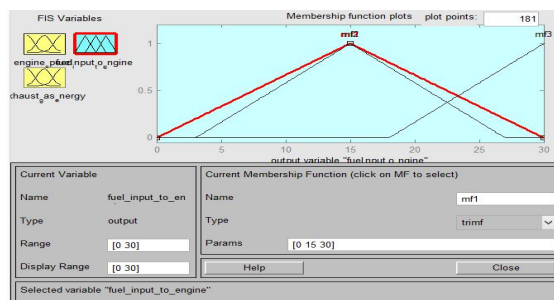


Fig.5 Membership functions of Fuel input to Engine.

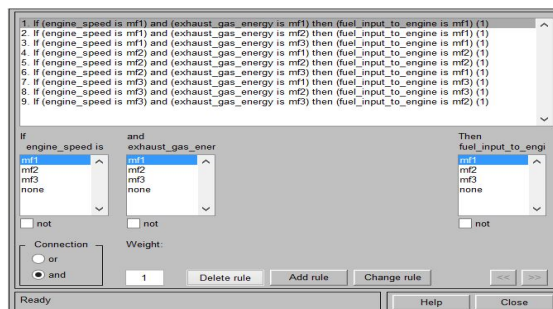


Fig.6 Rules of Fuzzy Logic controller.

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c. Algorithm of Fuzzy Inference System

The algorithm of Fuzzy Inference System is fully based on the fuzzy Logic Controller rules. The variables are used to assign the membership function as well as rules. The rules are fully based on the operating conditions of the variables. The variables are depending upon the operation of the engine. So the algorithm is based on the engine operating conditions. The main factor is considering for writing the algorithm is the device operating condition based on the proposal. The algorithm is to clarify the range and rules based on the variables in the fuzzy logic controller.

The algorithm of the Fuzzy Logic Controller:

[System]

Name='diesel_engine_1'
Type='mamdani'
Version=2.0
NumInputs=2
NumOutputs=1
NumRules=9
AndMethod='min'
OrMethod='max'
ImpMethod='min'
AggMethod='max'
DefuzzMethod='centroid'

[Input1]

Name='engine_speed'
Range=[0 3000]
NumMFs=3
MF1='mf1': 'trimf', [0 1500 3000]
MF2='mf2': 'trimf', [300 1500 2700]
MF3='mf3': 'trimf', [1800 3000 4200]

[Input2]

Name='exhaust_gas_energy'
Range=[0 100]
NumMFs=3
MF1='mf1': 'trimf', [0 50 100]
MF2='mf2': 'trimf', [10 50 90]
MF3='mf3': 'trimf', [60 100 140]

[Output1]

Name='fuel_input_to_engine'
Range=[0 30]
NumMFs=3
MF1='mf1': 'trimf', [0 15 30]
MF2='mf2': 'trimf', [3 15 27]
MF3='mf3': 'trimf', [18 30 42]

[Rules]

1 1, 1 (1) : 1
1 2, 1 (1) : 1
1 3, 1 (1) : 1
2 1, 2 (1) : 1

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- 2 2, 2 (1) : 1
- 2 3, 1 (1) : 1
- 10 1, 3 (1) : 1
- 10 2, 3 (1) : 1
- 10 3, 2 (1) : 1

C. Calculation of Additional Energy

The calculation of additional energy is the main consideration of the proposal. The additional energy is observed from the Exhaust gas when the engine operating condition. During the fast operation of engine due to high compression ratio and lack of timing of ignition of fuel to the engine the exhaust gas was produced. This gas has high temperature with more carbon particles. The removing of carbon particles and adding some thermal energy with that gas is used as additional energy to the engine.

Calculation:

The fuel consumption rate of one revolution of the engine(FC) = 25 mg/rev.

Maximum speed of the Engine (N) = 3000 rpm.

Fuel consumption rate when the maximum speed of the engine (FC) = 3000 × 25

$$FC = 75000 \text{ mg}$$

(Or)

$$FC = 75 \text{ g}$$

Approximately, Unburnt fuel of one revolution UBF = 5 mg/rev.

The unburnt fuel at maximum engine speed UBF = 15000 mg or 15 g.

Filter action on the Unburnt fuel (Exhaust gas) = 15000/ 1000

Weight of the filtered gas = 15 mg.

Additional energy from the filtered gas = 15 × 6.7

Additional energy to the engine (approximately)= 101.25 mg.

D. Engine Model with idle controller

Here, the generic engine model is used as diesel engine. It represents a system-level model of spark-ignition and diesel engines suitable for use at initial stages of modelling when only the basic parameters are available. An optional idle speed controller is included.

The throttle input signal T lies between zero and one and specifies the torque demanded from the engine as a fraction of the maximum possible torque. If the engine speed falls below the Stall speed, the engine torque is blended to zero. If the engine speed exceeds the Maximum speed, the simulation stops and issues an error message.

Connections F and B are mechanical rotational conserving ports associated with the engine crankshaft and engine block, respectively. Connections P and FC are physical signal output ports through which engine power and fuel consumption rate are reported.

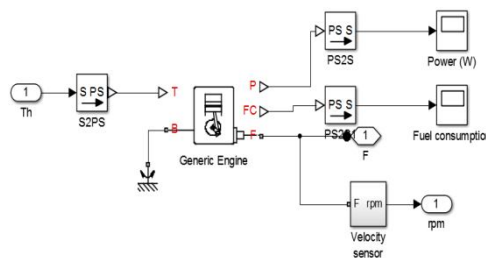


Fig.6 Engine model with idle controller.

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E. Proposed Simulink Model

The proposed Simulink model describes the engine operation, clutch operation, gear box and also vehicle body. The Driver inputs are gives the time of the gear changings and clutch and throttle control. The throttle signal was passed to Engine model, the clutch signal was passed to Clutch control and synchronizer signals (s_1, s_2, s_3, s_4) are passed to gear box from the driver input signal conditioner.

The output from the engine speed was give as input to the fuzzy logic controller. The calculation of additional energy from the exhaust gas as the second input variable to the FLC. During the execution of the model the increasing of speed gradually depending upon the load, the fuel consumption also gradually raised.

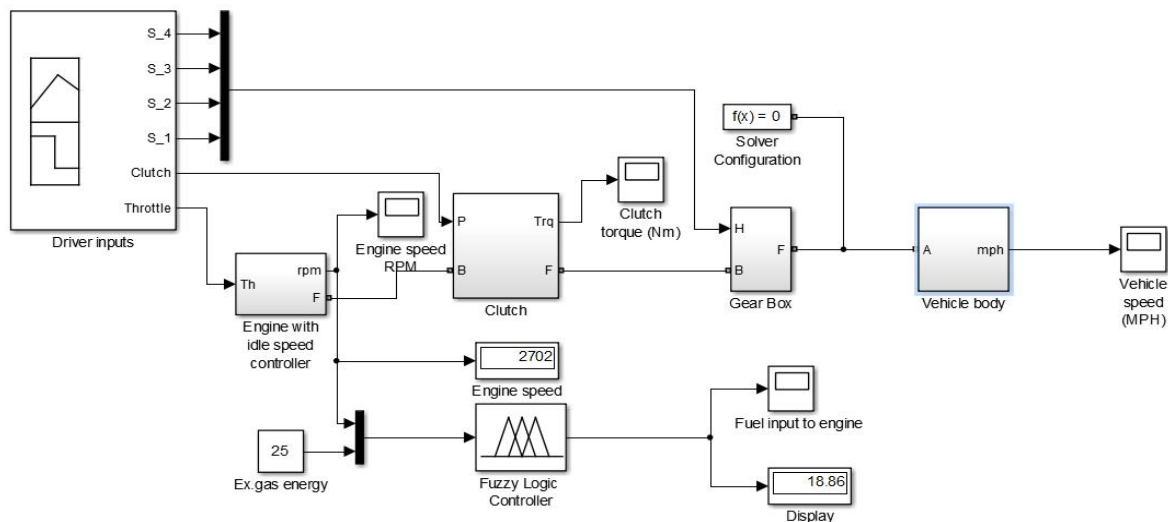


Fig.7 Overview of Proposed Simulink model.

F. Gear Box model

The gear box model represents the steps to changing the gear when the speed is needed to load through the engine. When the gear was change with help of clutch the position of the gear will be detected. The increasing of gear helps to increasing the speed of the engine. All steps of gear will have the position sensor and it is used to identify the operating gear. The synchronizer will be used for synchronizing the gear changing to engine shaft through the clutch control mechanism.

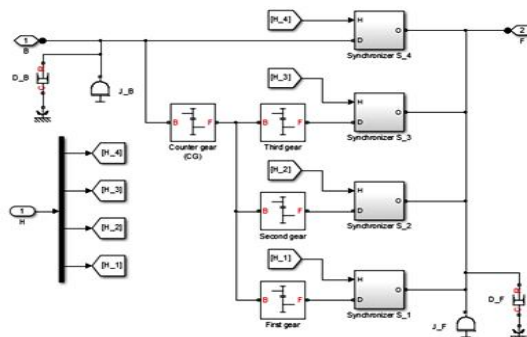


Fig.8 Gear box Simulink model.

The Gear Box block represents an ideal, non-planetary, fixed gear ratio gear box. The gear ratio is determined as the ratio of the input shaft angular velocity to that of the output shaft.

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The gear box is described with the following equations:

$$\omega_1 = N.\omega_2 \quad (1)$$

$$T_2 = N.T_1 \quad (2)$$

$$P_1 = \omega_1 \cdot T_1 \quad (3)$$

$$P_2 = - \omega_2 \cdot T_2(4)$$

Where,

- ω_1 - Input shaft angular velocity
- ω_2 - Output shaft angular velocity
- N - Gear ratio
- T_1 - Torque on the input shaft
- T_2 - Torque on the output shaft
- P_1 - Power on the input shaft
- P_2 - Power on the output shaft

III. RESULTS AND CONCLUSION

A. Fuel Consumption Rate

The fuel consumption rate is without and with additional energy is observed from the engine. The diesel engine operates with includes of additional energy the fuel consumption rate should be reduced. So it was indicates the pollution from the engine due to the exhaust gas was reduced. The fuel consumption rate from the engine is follows:

SI. No.	Engine Speed (rpm)	Fuel Consumption (without additional energy) (gm.)	Fuel Consumption (with additional energy) (gm.)
1	500	12.50	10.75
2	800	20.00	17.20
3	1000	25.00	21.50
4	1500	37.50	32.25
5	2000	50.00	43.00
6	2500	62.50	53.75
7	3000	75.00	64.50

Table.1 Fuel Consumption Rate Comparison

During the variations of speed the fuel consumption rate with and without additional energy was varied.

B. Fuel Input to Engine

The fuel input to the Engine is gradually rising with respect to speed. At the initial stage of the Engine the fuel consumption is more and it was reduced when the additional energy is added to the Engine. But the Power rate of the engine is maintained at the same rate.

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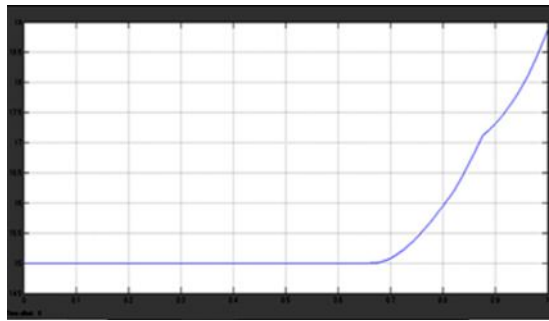


Fig.9 Fuel Input to the Engine.

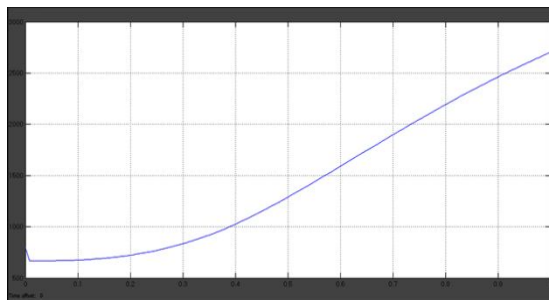


Fig.10 Engine Speed in rpm.

C. Conclusion

Thus the fuel input to engine has been observed from the engine with and without additional energy to the Engine. The result shows that the fuel consumption to the engine at maximum speed is reduced by the additional energy is added to the engine. So the pollution to the environmental is must be reduced.

D. Advantages

The advantages of the proposed model is given by,

- i. The compression ratio of the engine was reduced, due to additional energy.
- ii. The efficiency was increased.
- iii. Due to recycling of exhaust gas the environmental hazards (pollutions) will get reduced.
- iv. There is no need of any alteration or modify in the engine. So it can be applicable for new and existing engines.
- v. The fuel energy should be saved by utilization of waste energy.
- vi. Eco friendly engine control system.
- vii. To achieve the maximum speed with minimum time and minimum input (fuel).

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